S. C. DAVIDSON.
CENTRIFUGAL FAN OR PUMP.
APPLICATION FILED MAY 23, 1904.

INVENTOR:

Samuel Island Davidson,
By Attorneys,

WITNESSES:

Fred White
Rene Meurer
FIG. 5

FIG. 6.

FIG. 7.

INVENTOR:

Samuel Celand Davidson.

By Attorneys,

[Signature]

WITNESSES:

[Signatures]
To all whom it may concern:

Be it known that I, SAMUEL CLELAND DAVIDSON, a subject of the King of Great Britain and Ireland, residing in Belfast, Ireland, have invented certain new and useful Improvements in Centrifugal Fans or Pumps, of which the following is a specification.

This invention relates to rotary fans or pumps in which the fluid operated on is discharged under or against a material degree of back pressure or resistance as distinguished from such fans or pumps which circulate a large volume of fluid under or against little or no resistance. The multibladed drum form of centrifugal fan set forth in my Patent No. 662,396, granted November 27, 1900, has a high volumetric efficiency when operating purely as a ventilating-fan or under little or no back pressure or resistance. Its efficiency, however, diminishes as the resistance increases until a point is reached at which the type of fan shown in said patent possesses little if any advantage over other types of centrifugal fans which are designed for operating under or against considerable resistance.

The present invention is designed to improve the efficiency of centrifugal fans of the kind known as "pressure-fans," as distinguished from those known as "volume-fans." By "pressure-fans" I mean those commonly used for blowing forges, cupolas, or analogous purposes where the pressure on the discharge side of the fan is roughly speaking, from ten inches of water upward to any practicable maximum—say, for example, twenty inches of water or more. I also mean by this term those exhaust-fans which operate against similar suction resistances.

My present invention is based upon a discovery which I have made and utilizes what I believe to be a new principle of operation in centrifugal pressure-fans. I have ascertained by experiments with a centrifugal fan of drum form such as that set forth in my aforesaid patent, as shown, for example, in Figures 1 and 2, or Fig. 13 thereof, where the drum is inclosed in the usual form of spiral or snail-shaped casing, that the action is materially altered when either the inlet or the discharge is obstructed to cause a suction resistance or a back pressure as compared with that when the fan is running with a free inlet and discharge. Such a fan if unincased discharges the fluid radially from its blades and uniformly around its entire circumference in any given plane perpendicular to the axis of rotation. If inclosed in a snail-casing with a free discharge, this action is only slightly modified, due to the tangentially-discharged currents being collected by the casing and delivered in one stream through the discharge-outlet. If, however, the discharge is obstructed, an inequality of action around the circumference of the drum is caused, which inequality reaches its maximum when the discharge is wholly closed. Under these circumstances instead of the air flowing outwardly through the ports or spaces between the blades around the entire circumference of the drum such outward flow mainly occurs on one side of the drum, while on the opposite side there is a stream of fluid flowing first inwardly through the ports and then around inside the blades and finally passing outwardly again.

This action will be better understood from Fig. 1 of the accompanying drawings, which is a diagram corresponding in its proportions to Fig. 13 of my Patent No. 662,396. In this diagram A designates the fan-wheel or rotary drum, with its blades a a, and B designates the snail-casing, the inner outline only of which is shown. The eye or inlet-opening to the drum is indicated by the circle C. This eye thus is a circular opening of a diameter coincident with the outer edges of the blades. Sometimes it has been a circular opening of smaller diameter coincident with the inner edges of the blades, as indicated by the dotted line C. Assuming the outlet b of the casing to be closed and the drum rotated, the air-currents will be somewhat as indicated by the small arrows. As the precise direction of these currents varies with different back pressures, different diameters, and speeds of the drum, and other conditions, only an approximate illustration can be given. Taking, however, the example indicated, it will be seen that from a point indicated approximately at x around (in the direction of rotation) to another point approximately indicated at y, the air is discharged outwardly and tangentially from the blades, while beyond y and to a point adjacent to the nearest point z of the casing there is an inflow of air through the ports, and thence a current or stream c within the drum, which stream passes outwardly again between the blades adjacent to the point z. This current or stream c is of air under pressure. By measuring its velocity at different points within the drum a line may be plotted indicating what I may call the "inner" margin of the...
stream. This line is the dotted line \(d\). As its position varies with every variation of conditions, it is to be understood that this dotted line is only approximate. This stream of air has a tendency to outflow through the eye on that side coincident with the stream \(e\), so that by subdividing the eye with a flat plate in a plane coincident with the axis, extended approximately in a line between \(x\) and \(y\), an outflow will be found to occur on the left side of this plate and an inflow on the right side thereof. Throughout the intake-chamber or space inclosed between the blades to the right of the line \(d\) the condition of partial vacuum is found to be most marked near the inner edges of the blades on the sides most remote from the line \(d\).

It is a remarkable fact that the air-current \(e\) if unobstructed in its course travels at a higher velocity than the blades. Repeated tests have shown its velocity to be nearly or quite double that of the inner edges of the blades.

Another notable phenomenon is that exterior to the drum on the side where the current \(e\) in Fig. 1 exists there found to be a condition of rarefaction or partial vacuum, this space or chamber being approximately indicated by the letters \(e\). This vacuum diminishes gradually in traveling around with the drum and disappears in the neighborhood of the point \(x\). This vacuum-space is attended by some back-eddyning of the air near the outer wall of the casing, as indicated in Fig. 1 by the arrows pointing backward.

My present invention is based upon a recognition of the phenomena above stated. I have found by experiment that anything which obstructs the current \(e\) within the drum at once lowers the efficiency of the fan and defeats its object. Those fans in which occasional blades have been extended inwardly farther than their followers have had this result and are found by test to be notably inefficient under pressure. Accordingly I avoid placing anything within the drum which will materially retard the current or or retard it, and I permit it freely to flow with its wonted velocity—that is to say, considerably faster than the movement of the blades. I also provide means for preventing the axial escape of this current through the eye. I also reduce the vacuum-space \(e\) to the minimum, and thereby prevent eddy-currents therein, with accompanying loss, and reduce to a minimum the leakage of fluid between the exterior of the blades and the nearest portion of the casing. This leakage also involves a loss in efficiency. I also for a given size and capacity of the inclosing casing of the fan increase the diameter of the revolving member or drum and correspondingly vary the shape of the casing, whereby a greater centrifugal thrust is imparted to the air, so that it may be raised to a higher pressure. I also proportion the casing relatively to the size of the drum, so that the latter projects into the outlet portion of the casing to an extent preferably equal to about half the width of the discharge outlet.

I will proceed to describe first the principle of my invention and then the preferred embodiment thereof with reference to the accompanying drawings, wherein—

Fig. 1 is a diagram illustrating my former fan operating against a pressure, as already described. Fig. 2 is a similar diagram illustrating the operation of a fan proportioned and constructed according to my present invention. Fig. 3 is a diagrammatic or outline elevation of the casing of the fan shown in Fig. 2. Fig. 4 is a comparative diagram illustrating the proportions of Fig. 1 and Fig. 2 superposed the one upon the other. Fig. 5 is a vertical section of a fan, illustrating the preferred construction embodying my invention. Fig. 6 is a vertical section thereof in a plane intersecting the axis. Fig. 7 is a similar section to Fig. 6, illustrating a modified construction. Figs. 8 and 9 are vertical sections in the same planes as Figs. 5 and 6 showing a modified construction.

In this specification the word “fan” is understood as including a pump. The word “axially” means in a direction coincident with or parallel with the axis of rotation. The word “blades” is used to indicate the vanes or wings which impart motion to the fluid. The expression “intake-chamber” is employed to indicate a chamber or space inclosed within the series of blades. The word “eye” is used to designate the opening through which the fluid enters the intake-chamber. By the “intake” end of the drum or its intake-chamber or its blades or ports is understood that end which is nearest the eye. The “depth” of the blades is their width measured radially from the inner to the outer edge. The “length” of the blades is their axial measurement, and the “ports” are the intervening spaces between the blades.

Referring first to Fig. 2 and comparing it with Fig. 1, it will be seen that the drum A is relatively enlarged, while the casing B is constructed. The casing instead of approaching the drum closest at the point \(z\), Fig. 1, where, nevertheless, there is considerable leakage, approaches it as closely as practicable from the point \(f\) for a suitable distance, usually about one-fourth of the circumference of the drum, sufficient to largely eliminate the vacuum space \(e\) of Fig. 1, so that this portion of the casing from \(f\) to \(f'\) is concentric, or substantially so, with the drum. From the point \(f'\), where the casing begins to leave the drum, it gradually separates therefrom in a spiral curve, which, however, does not depart so far from the exterior of the drum as in the former construction, the extreme departure being preferably about one-half the width of
the discharge-outlet \( b \), so that the middle line of this outlet shall tangent the drum. Preferably the casing is carried directly downward from the point \( f \), which is on a level with the drum-axis, to the upper side of the outlet, so as to leave a tapering space \( g \), into which air can enter to facilitate the inflow of the current \( c \) through the ports to the interior of the drum. The inner limit or margin of this current may or may not be approximately parallel to the outer wall of the casing, the contour of the current varying, as stated, with every variation in the conditions of pressure, speed, &c., under which the fan may be working. The eye \( C \) may have the same area as in the former construction, but is here shown as contracted to the diameter of the dotted circle \( C \) in Fig. 1. By reason of the enlargement of the drum the eye has a considerably smaller area than the intake-chamber. It is practically important that the eye shall be mainly within the limit of the compressed-air current \( c \) — that is, preferably within the contour of the line \( d \). Ideally the eye should be entirely within the line \( d \), as indicated, for example, by the line \( h \) in Fig. 2. Such contracting of the eye realizes completely an important desideratum of my invention — namely, the prevention of the escape of the fluid under pressure constituting the current \( c \). As in practical operation power has been exerted to set the entire mass of fluid in rotation, any escape of this whirling air involves a loss of power, which must be made up by again setting in motion an equal quantity of air. Thus by preventing the escape of air from the current \( c \) by contracting the eye at \( h \) I avoid this loss of power and greatly increase the efficiency of the fan as a pressure-fan.

The contour of the current, and consequently the location of the line \( d \), is liable to frequent change. For example, in Fig. 3 the line \( d \) may denote the inner margin of the current under one condition — for example, that of minimum resistance — while the line \( d^2 \) may indicate the inner margin of the current under a different condition — for example, that of maximum resistance.

It is not necessary that the eye shall be wholly within the current margin \( d \), but slight loss would ensue if the eye were to coincide with the inner portion only of the current \( c \), as is the case shown in Fig. 2, where the eye encroaches upon the current for a short distance, so that the marginal line \( d \) actually crosses the eye.

The differences between the former proportions and those in my present invention may be readily seen with reference to Fig. 4, where the dotted lines show the old proportions, as in Fig. 1, and the full lines show the new proportions, as in Fig. 2, only a small section of the fan-blades being shown in each instance. The eye shown of the diameter \( C \) in Fig. 1 is unaltered, so that the volumetric capacity remains the same. The rotary fan member or drum is enlarged to afford an axially-confined space within the drum for confining the back current \( c \). The pitch of the spiral of the casing is reduced and the discharge-outlet is raised and narrowed, so that instead of its upper margin being level with or on a tangent to the lower circumference of the drum the middle of the outlet is on such tangent, or, in other words, the drum projects down into the casing half the depth of the outlet. The narrowing of the outlet vertically may require widening it and the entire fan horizontally to afford the requisite volumetric capacity. The casing instead of being wholly spiral is partially concentric with the drum. It is practically important that the eye be of sufficient area so that the speed of inflow of the fluid need not exceed the speed of discharge thereof from the outlet.

Figs. 5 and 6 show a fan constructed according to my invention. In these figures, \( A \) is the rotary member or drum, and \( B \) the casing. The blades \( a \) and \( b \) are curved, being concave on the advancing sides and pitched slightly forward at their outer edges, as disclosed in my said Patent No. 652,395, to which reference is made for an illustration of the details of attachment and construction. The circular series of blades is shown in Fig. 6 as connected to the central revolving shaft \( D \) by means of a disk \( E \), forming the closed inner end of the drum, the opposite side of the drum being open at the eye \( C \). In Fig. 6 the casing is shown with an inlet-opening at least as large as the eye, the latter being concentric, as shown in Fig. 5. In this case the eye is formed of an annular plate \( F \) forming part of and turning with the drum, its outer portion serving for the attachment of the ends of the blades, while its inner portion within the blades serves to inclose the outer annular portion of the intake-chamber, the opening formed within its inner edge constituting the eye. Preferably the inner edge of the plate \( F \) is curved inwardly slightly, as shown. This construction has the advantage of forming a strong and well-braced drum which requires no internal tie-rods or braces to stiffen it. This construction of course necessitates that the eye shall be concentric.

Fig. 7 shows a modification wherein the eye is formed in the casing. In this case an annular metal plate \( F \) is used to which to fasten the ends of the blades, and the outer plate \( G \) of the casing is extended inward beyond this plate, so that its inner margin forms the boundary of the eye.

It is preferable to curve the casing at \( g \), Fig. 5, between the point \( f \) and the outlet to ease the flow of the back current into the ports between the blades.

In Figs. 5, 6, and 7 I have shown the blades
somewhat deeper in proportion to the diameter of the drum than in the preceding diagrams. My invention is not limited to any definite proportion between the depth of the blades and the diameter of the drum or between their depth and length. In the construction of pressure-fans according to my present invention I may advantageously make the blades shorter and deeper than the proportions stated as preferred in my former patent.

Fans constructed according to my present invention when employed as pressure-fans attain a greatly-increased power efficiency as compared with prior fans constructed either on the principle disclosed in my aforesaid patent or according to the ordinary types of centrifugal fans which have long been used. Thus for a given service I am able to effect a very important economy in power and reduction in size of casing. My improved fan has also the important advantage of being practically noiseless or free from the whirring or beating sound or "organ note" which is a common accompaniment of centrifugal fans.

My invention is particularly advantageous when the fan is required to deliver a relatively large rather than a small volume of air against a considerable resistance.

The present invention is not limited to what I have herein referred to as the "drum form" of fan, nor to the general type of fans set forth in my aforesaid patent. It is also applicable, but with less advantage, to centrifugal fans of the ordinary pressure-blower type. As one illustration of such application of my invention I show in Figs. 8 and 9 a fan somewhat resembling the ordinary pressure-blower, but modified so as to embody in part the principles of my invention. In these figures, A is the rotary member or fan-wheel, and B the casing. The rotary member has curved blades α, usually mounted between conical or frilled plates H II, one or each of which has a central opening forming the eye. Such rotary member may be variously mounted—for example, by means of a central disk I, attached at its outer part to the blades and at its center to a hub on the shaft D'. It is common in the construction of such fans to provide a series of short blades of approximately the shape of the blades α and at intervals to extend these blades inwardly, forming long blades, as shown in dotted lines at α. These inward extensions α′ have been thought necessary to impart the requisite pressure to the air. They have been commonly tapered at their inner edges in the manner shown by dotted lines α′ in Fig. 9. They have commonly projected more or less within the circumference of the eye. In applying my invention to a fan of this character it is necessary to cut away the portions α′, preferably entirely, so that all the blades shall be of the same depth, as shown by full lines in Fig. 8, thereby affording a free and unobstructed space within the series of blades for the flow of the back current through and across the rotary member.

Although I have described my invention as a fan for acting upon air, yet it is to be understood that it is applicable also with other fluids. It is highly advantageous for use as a centrifugal pump for water or other liquids. The operation with a liquid differs from the operation with air only to the extent that the fluid operated upon is incompressible. By loosening these clamps the plate G may be shifted to either vary the eccentricity of the eye or to vary its lead. Thus if the fan is to be used under different conditions at different times the plate G may be shifted to bring the eye to the best position for any given use. This position may be ascertained in any case by experiment, or a larger or smaller eye may be provided by removing the plate G and substituting another plate having a larger or smaller opening.

My invention may be modified in many respects without departing from its essential features.

I claim as my invention—

1. A centrifugal fan or pump, comprising a snail casing, and a fan-wheel mounted eccentrically therein, whereby when operating against a pressure or suction there is established a current of fluid moving inwardly through the ports of said fan-wheel and across the intake-chamber thereof, that portion of said intake-chamber traversed by said current being practically unobstructed, and said fan or pump having means for opposing the outflow of fluid axially through the intake end.

2. A centrifugal fan or pump, comprising a snail casing, and a fan-wheel mounted eccentrically therein, whereby when operating against a pressure or suction there is established a current of fluid moving inwardly through the ports of said fan-wheel and across the intake-chamber thereof, that portion of said intake-chamber traversed by said current being practically unobstructed, and said fan or pump having means for opposing the outflow of fluid axially through the intake end, said means comprising a plate having an eye which is smaller than the intake end of said chamber.

3. A centrifugal fan or pump, comprising a snail casing, and a fan-wheel mounted eccentrically therein, whereby when operating against a pressure or suction there is established a current of fluid moving inwardly through the ports of said fan-wheel and across the intake-chamber thereof, that portion of said intake-chamber traversed by said current being practically unobstructed, and said fan or pump having means for opposing the outflow of fluid axially through the intake end, said means comprising a plate fixed to said casing and having an eye concentric to the
axis of said fan-wheel and smaller than the intake end of said chamber.

4. A centrifugal fan or pump, having means for opposing the axial outflow of fluid through its intake end and having a substantially unobstructed space within the blades, and having a snail casing fitting close around the outside of the fan-blades from the discharge-outlet and for about one-fourth of the circumference of the fan-wheel in the direction of its rotation, to keep the inwardly-returned current of air coming from the discharge-outlet from passing outwardly again between the fan-blades, until it nearly approaches the diametrically opposite side of the fan-wheel from the discharge-outlet.

5. A centrifugal fan or pump having the space within its blades substantially unobstructed, and having a snail-shaped casing fitted close around the outside of the fan-blades from the discharge-outlet, and for about one-fourth of the circumference of the fan-wheel, in the direction of rotation, to keep the inwardly-flowing current which is returned from said discharge-outlet from passing outwardly again between the blades until it nearly approaches the diametrically opposite side of the fan-wheel from the discharge-outlet, said casing being extended inward on the intake end of the fan-wheel close against the intake ends of the blades, and inwardly beyond the same, so as to form a concentric eye, wholly within the inner margin of the blades, so as to axially confine the flow of said fluid.

6. A centrifugal fan or pump having a snail-shaped casing fitted close around the outside of the fan-blades from the discharge-outlet, and for about one-fourth of the circumference of the fan-wheel, in the direction of rotation, to keep the inwardly-flowing current, which is returned from said discharge-outlet, from passing outwardly again between the blades until it nearly approaches the diametrically opposite side of the fan-wheel from the discharge-outlet, said casing being extended inward on the intake end of the fan-wheel close against the intake ends of the blades and inwardly beyond the same, so as to form a concentric eye wholly within the inner margin of the blades, so as to axially confine the flow of said fluid, said eye having its edge curved toward the interior of the fan-wheel.

In witness whereof I have hereunto signed my name in the presence of two subscribing witnesses.

SAMUEL CLELAND DAVIDSON.

Witnesses:
ROBERT MILLER BAILY,
JOSEPH H. BAILY.